Journal of Arid Environments 129 (2016) 93–101

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Composition, species richness, and density of the germinable seed bank over 4 years in young and mature forests in Brazilian semiarid regions

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ARTICLE INFO

Article history:
Received 3 October 2014
Received in revised form
15 February 2016
Accepted 19 February 2016
Available online 1 March 2016

Keywords:
Caatinga
Seedling emergence
Natural regeneration

ABSTRACT

The soil seed bank is an important ecological component in forest regeneration. In semiarid regions, forest regeneration is highly affected by seasonal and interannual variations in precipitation, because these variations may affect the composition, species richness, and density of seeds in the soil. This study aimed to characterize and compare these parameters of the germinable seed bank in fragments of young and mature Caatinga forest between various seasons and over consecutive years. A total of 105 soil samples were collected in 20 × 20 × 5 cm plots in each forest (Young and Mature) at the end of the rainy and dry seasons over 4 years (2009–2012), totaling 840 samples. The composition, species richness, and density of seeds were determined by the method of seedling emergence. Over the 4 years, 121 species emerged from the soil seed bank, 86 in the young forest, and 109 in the mature forest. Significant differences in the composition, richness, and density were recorded between forests, seasons, and years, with a significant interaction between them. Relationship between rainfall and age of forests affects the dynamics of the soil seed bank in semiarid environments, which are important distinctions for the maintenance of these areas.

1. Introduction

Severe anthropogenic disturbances, including complete destruction of bushland for the establishment of pasture lands and agriculture, have modified dry and humid environments in the world and endangered climatic characteristics as well as maintenance of ecosystem function and biodiversity conservation, necessitating the comprehension of their influence on natural regeneration, which involves resilience of forests (Santos et al., 2013a; Esaete et al., 2014; Randriamalala et al., 2015; Valenta et al., 2015).

Among the processes involved in the regeneration of forests, the dynamic of seed bank plays an important role in carrying the germplasm, which enables the formation of new secondary forests and re-acquirement of areas previously occupied by humans (Kassahun et al., 2009; Golos and Dixon, 2014). However, type of and historical land use, associated with local climate changes, generates complexity on the dynamic of soil seed bank, considering the variation of the time taken for the recovery of species composition and structure of forests (Heydari et al., 2014; Mendes et al., 2015).

Despite the complexity, three trends are reported: (1) With increased level of degradation of such area, a decrease in seed density and species richness of the soil seed bank occurs (Karlík and Pochlod, 2014; Mendes et al., 2015). (2) The new secondary forests consisting of abandoned areas of agriculture and pasture show changes in species composition and population density and low similarity with species composition of soil seed bank (Pereira et al., 2003; Kassahun et al., 2009; Heydari et al., 2014). (3) The recruitment and regeneration of degraded areas highly depend on the dormancy capacity of the seeds stored in the soil bank (Liu et al., 2009; Golos and Dixon, 2014).

However, interannual variations in precipitation can increase the complexity and modify the trends reported in the literature,

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http://dx.doi.org/10.1016/j.jaridenv.2016.02.012
0140-1963/

particularly in semiarid regions with well-defined rainy and dry seasons, because they induce differences in the time of production of fruits and seeds (Selwyn and Parthasarathy, 2006; Valdez-Hernández et al., 2010; Souza et al., 2014), thereby affecting dispersal and seed rain. For instance, interannual variations and irregularities in quantitative and rainfall distribution have a significant effect on the reproductive behavior of plants (Albuquerque et al., 2012; Santos et al., 2014) and the intensity of seed rain (Souza et al., 2014) in the vegetation of Brazilian semiarid Caatinga. This explains part of the wealth of species and seed density found in the soil bank of mature forests of this type of vegetation (Silva et al., 2013).

Thus, this study characterizes and compares the composition, species richness, and density of the germinable seed bank in young and mature forests of Caatinga between various seasons and over consecutive years. In particular, we investigate whether (1) the species richness and seed density of the soil bank are smaller in the young forest, after 15 years of abandonment of agricultural activity; (2) anthropogenic disturbance and seasonal and interannual variations in rainfall affect the floristic composition of the remaining soil seed bank; and (3) the species richness and seed density of the soil seed bank are lower in dry seasons and driest years than in the rainy seasons and wettest years, in both young and mature forests.

2. Material and methods

2.1. Characterization of the study area

The study was conducted at the Agronomic Institute of Pernambuco – IPA (8° 14′ S and 35° 55′ W, 537-m altitude), located in the municipality of Caruaru, Pernambuco, Brazil. The site is located in the rural zone at a distance of 9 km from the nearest city. This is a semiarid region, with minimum and maximum temperatures of 11 and 38 °C, respectively. The average annual rainfall is 694 mm and the rainy season spans from March to August, with few months having rainfall >100 mm.

The dry season spans from September to February, with average monthly rainfall of <30 mm. However, occasional or erratic rainfall may occur in the dry season and dry spells may occur in the rainy season (Araújo et al., 2005a). The range of total rainfall recorded in the study years 2009, 2010, 2011, and 2012 is 350.8–1031.2 mm (Fig. 1). The local seasonality determines the deciduousness of the woody flora in the dry season, and therophytic herbs can only be observed in the rainy season (Santos et al., 2013a). Moreover, seasonal variations in rainfall influence the rhythm of seed rain in the local vegetation, existing in three species groups: (1) species that disperse seeds only in the rainy season; (2) species that disperse seeds only in the dry season; and (3) species that disperse seeds throughout the year (Souza et al., 2014).

The experimental site occupied an area of 190 ha and was created with the primary aim of developing research for agriculture and livestock activities. Before the experiment, the area was occupied by a single patch of mature Caatinga vegetation; however, the current native vegetation is reduced to a small fragment of approximately 30 ha of mature forest. In this area, woody species of the families Mimosaceae, Caesalpiniaceae, Euphorbiaceae, and Cactaceae (Alcoforado-Filho et al., 2003; Araújo et al., 2007) form a closed canopy, which provides a longer period of soil moisture (Santos et al., 2013b).

Species of the families Poaceae, Euphorbiaceae, Convolvulaceae, Malvaceae, Asteraceae, and Fabaceae (Araújo et al., 2005a; Reis et al., 2006) predominate in the herbaceous component. This fragment has been preserved for approximately 50 years by not allowing the entry of animals and removal of vegetation (Lopes et al., 2012; Santos et al., 2013a). This fragment is the first area of study, and is named the mature forest.

For the last 19 years, a stretch of 3 ha near the mature forest suffered clear-cutting for the cultivation of *Opuntia ficus-indica* Mill., Cactaceae (commonly called “sweet palm”) (Santos et al., 2013a). No fire, fertilizer, or manure was used during the period of cultivation (Lopes et al., 2012; Souza et al., 2014). After 6 months, this fragment was abandoned and the young forest regenerated naturally. Currently, the herbaceous component of the young forest has rich species of Poaceae and Cyperaceae (Santos et al., 2013a) and the woody component is represented by some young species such as *Poincianella pyramidalis* (Tul.) L.P. Queiroz (catingueira), *Acacia paniculata* Willd. (unha de gato), and *Anadenanthera macrocarpa* (Benth.) Brenan (angico) (Lopes et al., 2012), which do not form a closed canopy, thereby promoting a higher incidence of light in this area (Andrade, unpublished data). This fragment is named the young forest.

2.2. Samples of the soil seed bank

For both mature and young forest fragments, there exists a fragment of 1 ha, where studies on the woody and herbaceous

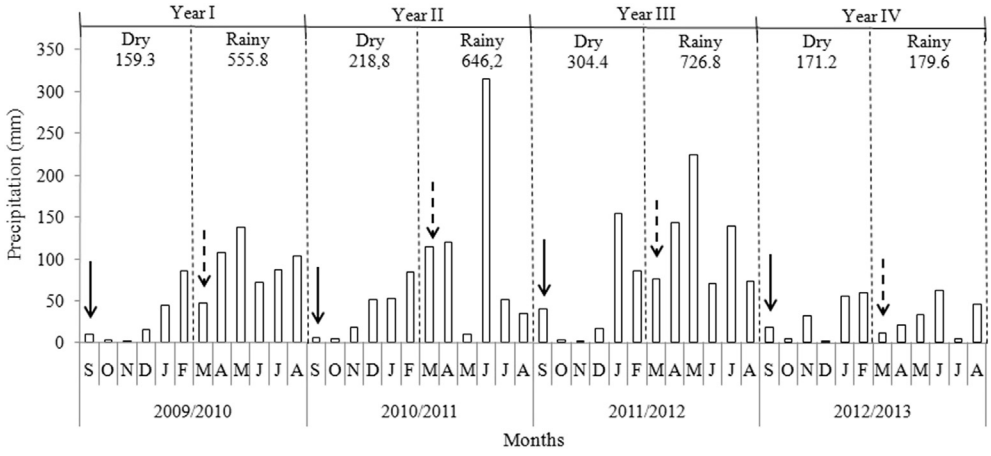

Fig. 1. Monthly precipitation and total precipitation during the rainy and dry seasons over 4 years. Solid arrows indicate the samples collected at the end of the rainy seasons and dashed arrows indicate the samples collected at the end of the dry seasons. Data were provided by the meteorological station of the Empresa Pernambucana de Pesquisa Agropecuária (IPA) in Caruaru, Pernambuco, Brazil.